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Letter to the Editor

Which photometric period for WR 16?*

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Summary

Analysis of new and already published photometric observations shows that the Wolf-Rayet star WR16 = HD86161 is not the binary system (WR + compact, $P = 5.365$ d) claimed by Moffat and Niemela (1982). Instead it is shown that the simultaneous presence of two periodicities (about 1.3 and 2.5 days) is necessary to account for the observed variations during at least one observing run. The variability of the B9p star HD86199, previously used as a comparison for a photometric study of WR16, is established.

Key words : Wolf-Rayet stars - *b* photometry

1. Introduction

WR16 (= HD86161) is a WN8 star whose variability has been interpreted as the signature of a binary system (WR + compact) by Moffat and Niemela (1982). On the basis of their 1975 photometric observations, they derived a single wave light curve with a period of $P = 5.365$ d. Arguing that *"a single wave is physically difficult to account for"* and that *"the best spectroscopic data suggest a longer period, **if anything** "* they conclude that WR16 is an ellipsoidal variable with a period of 10.73 d . As a matter of fact, the published value of the semi-amplitude of the radial velocity curve ($K = 6$ km sec^{-1}) is the lowest ever reported for a WR binary, and the possibility of reaching such an accuracy can be questioned because of the large intrinsic line width of those objects (thousands of km sec^{-1}). This explains the large scatter of the phase diagram and the difficulty to derive any secure period from the radial velocity data.

The period published by Moffat and Niemela is essentially based on differential photometric observations made by using alternatively two B stars (HD86441 and HD86199) as comparisons. The former turned out to be a variable with a period of 5.73 days and a primary minimum depth of the order of 0.10 mag (Moffat, 1977). The other star, HD86199, showed no indication of variability but the authors give no information about the accuracy of their measurements. As a matter of fact our 1987 observations indicate that HD86199 varies precisely with the period quoted by Moffat and Niemela (1982) for WR16. Recent photometric observations of WR16 are reported by Van Genderen *et al.* (1987) using another comparison star, HD86000. Their observations are not numerous enough to allow any independent search for periodicity. As a consequence they *a priori* adopt the same period as Moffat and Niemela (1982) and conclude to the existence of a large intrinsic scatter around the mean light curve.

(*) Based on observations collected at the ESO Observatory, Chile

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Using our own observations as well as those by Moffat and Niemela (1982) we will reinvestigate in the present paper the variability of WR16, addressing three questions:

is there any periodicity in the photometric data?

if a period is suggested by one of the data sets, is this period stable on a longer time scale?

and finally, do we have evidence for short time scale (hours) variability?

2. Observations and reductions

The observations were carried out with the ESO 50cm telescope of the European Southern Observatory, La Silla. The standard one-channel photometer was equipped with the Strömgren *b* filter.

The observational sequence adopted for the differential measurements was $C_1C_2VC_1C_2VC_1C_2VC_1C_2V$ where V denotes the WR star and C_1 and C_2 the comparison stars (HD86000 and HD86199). Each individual measurement consisted of short integrations totalling 80 to 120 seconds and an entire sequence lasted between 20 and 30 minutes. Typically three such sequences were performed every night so that variations on a time scale of a few hours could have been detected.

Useful data were obtained on 12 nights between March 29 and April 10, 1987. The reduction procedure is based on the method explained by Manfroid and Heck (1983, 1984).

3. Results

3.1. The variability of HD86199

The analysis of the magnitude difference between HD86000 and HD86199 shows a clear variation with a total amplitude of about 0.025 mag. The same variation pattern is found in the differential data for WR16 - HD86199 and hence can be attributed to HD86199, an Ap (B9Si) star (Houk and Cowley, 1975). To our knowledge the variability of this star has never been reported. A period search has been performed both in our data and in those of Moffat and Niemela (1982) with the Wolf-Rayet as a comparison.

Figure 1 shows the resulting phase diagram in the case of HD86199 – HD86000, calculated for the adopted period of 5.494 days. In fact the period determination yields many possible values because of the uncertainty on the number of cycles elapsed between both observing run. In the frequency domain we have

$$\nu = 0.182038\ (\pm 0.000010) \pm n\, 0.000226\ \mathrm{d}^{-1} \quad n < 20$$

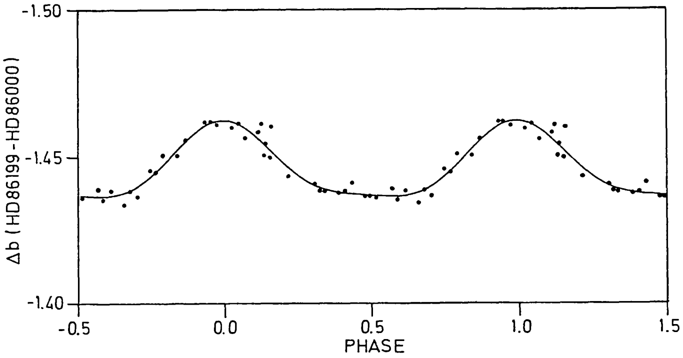

Fig. 1. Phase diagram of the B9p Si star HD86199 plotted for a period of 5.494 days. Phase zero corresponds to JD 2446894.90. The curve represents a fit by a sine wave and its first harmonic.

The mean light curve has been fitted by a sine wave and its first harmonic

$$\Delta b\,(t) = A_0 + A_1 \cos(2\pi \frac{t - t_0}{P} + \Phi_1) + A_2 \cos(4\pi \frac{t - t_0}{P} + \Phi_2)$$

The parameters have the following values ($\pm$ one standard deviation)

$A_0 = -1.4464$	(± 0.0005)
$A_1 = -0.0127$	(± 0.0007)
$\Phi_1 = 0°$	$(\pm 4°)$
$A_2 = -0.0031$	(± 0.0007)
$\Phi_2 = 10°$	$(\pm 13°)$
$t_0 = 2446894.90$	

The analysis of the variability of HD86441 published by Moffat (1977) was based on a comparison between that star and HD86199. One could wonder if the present discovery of the variability of HD86199 has some influence on those results. An important effect is certainly not expected because of the much larger amplitude of HD86441 relative to HD86199. To check it we have removed from Moffat's data on HD86441 – HD86199 the variations due to HD86199 as derived from our own data. These "corrected" data give results virtually identical to those obtained by Moffat although the lightcurve is somewhat smoother.

3.2. Variability of WR16

3.2.1. Analysis of our data

From our 1987 data it is clear that WR16 is photometrically variable but at first glance the variations are somewhat irregular. The differential magnitudes have been analyzed by Fourier techniques up to a frequency of 10 d^{-1}. As one could have expected from the previous discussion, the power spectrum does not show the periodicity reported by Moffat and Niemela (1982). No short time scale variations are visible either. The main peaks are all below the frequency $\nu = 1.0\ d^{-1}$.

A detailed analysis puts forward two frequencies: $\nu = 0.735\ d^{-1}$, i.e $P = 1.36$ d, (or the less likely alias $\nu = 0.273\ d^{-1}$, i.e $P = 3.66$ d), is the most important one while $\nu = 0.397\ d^{-1}$, i.e $P = 2.52$ d, (or the less likely alias $\nu = 0.608\ d^{-1}$, i.e $P = 1.645$ d), is only slightly weaker. In both cases the deviation to randomness exhibits a significance level better than 0.005 when estimated by the method of Scargle (1982). Since two frequencies are present, it is necessary to improve their values as derived by the Fourier spectrum, by making a non-linear fit. This leads to $\nu_1 = 0.744\ d^{-1}$ ($P = 1.344$ d) with an amplitude of 0.0124 mag, and $\nu_2 = 0.392\ d^{-1}$ ($P = 2.55$ d) with an amplitude of 0.0098 mag.

As can be seen on Figure 2, two sines with the derived periods yield a satisfactory fit to the observed variability. This simplicity is a good argument in favour of the reality of the periodicities. Unfortunately their consistency cannot be tested over such a short time base. This means that we may be dealing with a particular realization of a random variation of the star. More insight could only come from other data sets.

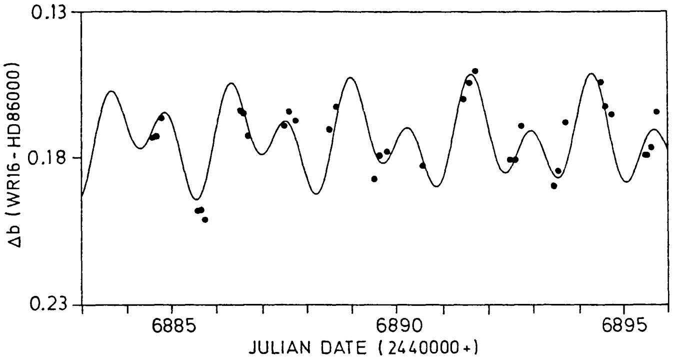

Fig. 2. Observations of the Wolf-Rayet star WR16 = HD86161. The curve represents a fit by two sine curves with frequencies $\nu = 0.744\ d^{-1}$ and $\nu = 0.392\ d^{-1}$.

3.2.2. Analysis of previously published data

The original data of Moffat and Niemela (1982) have the advantage of a long time span. As shown in a preceding section, the comparison star they used (HD86199) proved to be variable. Trying to draw out as much information as possible we tentatively removed from those data the variation due to HD86199 as determined from our 1987 observations. The modified data were submitted to a Fourier analysis: Figure 3 shows the relevant Periodogram Estimate of Scargle (1982).

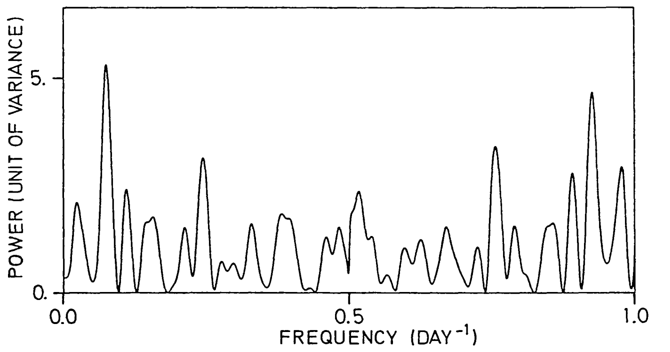

Fig. 3. Scargle's periodogram estimate for WR16 calculated from Moffat and Niemela's (1982) corrected data (see text).

Two alias families are visible. A first peak corresponds to a frequency $\nu = 0.0765\ d^{-1}$, i.e $P = 13.1$ d, (or its alias $\nu = 0.9235\ d^{-1}$, i.e $P = 1.082$ d), while the second one is located at $\nu = 0.755\ d^{-1}$, i.e $P = 1.324$ d, (or its alias $\nu = 0.245\ d^{-1}$, i.e $P = 4.08$ d). The periodogram is noisy, as can be expected after our manipulations; the deviations to randomness are not significant by themselves. We note however that the frequency $\nu = 0.755\ d^{-1}$ agrees nicely with our value of ν_1. No such comparison can be attempted for the other variation with $\nu = 0.0765\ d^{-1}$ which corresponds to a period longer than our observing run.

If both data sets (the 1975 observations by Moffat and Niemela and our 1987 data) are put together, the power around $\nu = 0.75\ d^{-1}$ does not decrease at all. In fact it is somewhat enhanced. This indicates some long term coherency but extreme caution is necessary due to the scarcity of high quality data.

Although they are few, we decided to analyse the photometric data by Van Genderen *et al.* (1987) in the Walraven system. Two alias families stand out: the first one corresponds to $\nu = 0.570\ d^{-1}$, i.e $P = 1.75$ d, (or its alias $\nu = 0.430\ d^{-1}$, i.e $P = 2.32$ d), and the other corresponds to $\nu = 0.745\ d^{-1}$, i.e $P = 1.34$ d. The sole presence of the latter frequency is amazing. Moreover, because of the large width of the peaks profile in the power spectrum, the value $\nu = 0.430\ d^{-1}$ is not completely incompatible with $\nu = 0.397\ d^{-1}$ discovered in our data. Unfortunately the size of the Van Genderen *et al.* data set does not allow a definite conclusion.

4.Conclusions

From our new photometric observations we can draw the following conclusions.

The star HD86199 (B9pSi) used by Moffat and Niemela (1982) as a comparison for the study of WR16=HD86161 is variable and responsible for most of the variability claimed by these authors for the Wolf-Rayet.

WR16 is photometrically variable with an amplitude of the order of 0.05 mag.

The period of 5.365 days previously claimed for that star is present neither in our data nor in the data by Moffat and Niemela, once corrected for the variability of the reference star.

There is no evidence for short time scale periodicity (periods from a few hours up to a day).

Our data can be fairly well reproduced by the simultaneous existence of two frequencies $\nu_1 = 0.744\ d^{-1}$ ($P = 1.344$ d) and $\nu_2 = 0.392\ d^{-1}$ ($P = 2.55$ d) (or their aliases). Unfortunately the length of our observing run does not allow us to ascertain the true periodic nature of the observed variability and an ephemeral pseudo-periodic behaviour cannot be excluded.

The data of Moffat and Niemela, corrected for the variations of the reference star show marginal evidence for two frequencies $\nu = 0.0765\ d^{-1}$ ($P = 13.1$ d) and $\nu = 0.755\ d^{-1}$. ($P = 1.32$ d) and The latter is very close to one of the frequencies present in our data: due to the uncertainty generated by the width of the peaks in the periodogram, they could be identical. This frequency is also compatible with the data by Van Genderen *et al.* so that there is some hints for a long term coherency of the variability associated with it.

Although our new observations do not allow yet to unravel the true nature of the variability of WR16, they clearly indicate that this star is certainly not the binary claimed by Moffat and Niemela. They also raise the interesting question of the simultaneous presence of two frequencies. Repeated high quality observations over a long time base are clearly needed. Let us hope that this letter will stimulate more observers to tackle this demanding observational problem.

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